Illinois River Water Level Management Analysis

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Abstract

As a part of the Illinois River Ecosystem Restoration Feasibility Study, the Hydrology and Hydraulics Branch of the Rock Island District, USACE, investigated the potential to change water level management activities on the Illinois Waterway in order to provide ecosystem benefits, primarily by reducing rapid water level fluctuations. Analysis of gage records confirmed observations that changes in the Illinois River Basin have resulted in a more fluctuating water level at many points along the Illinois Waterway than had occurred prior to 1900. Water level management was determined to contribute to fluctuation at some points in this system, specifically in the reaches immediately downstream of navigation dams, in part due to the hydraulic nature of the flat pools, the methods of operation and the highly variable inflows from the watershed. Unsteady hydraulic modeling indicated that management changes could reduce these fluctuations; smaller but more frequent gate changes at the dams would significantly reduce the total number of 0.5 foot or greater fluctuations along the river. However, the reduced fluctuations would generally have occurred during times of low water and so may not be as ecologically important as larger, out-of-banks events. Also, period-of-record hydraulic modeling was used to evaluate the seasonal potential to draw the Peoria Pool down to stabilize sediments and allow plant establishment. Drawdowns are most likely to be successful in the months of September or October, or if attempted over an extended period of time in the late summer.

Background

The Illinois River drains a 30,000 square mile basin encompassing portions of Illinois, Indiana and Wisconsin (Figure 1). Prior to 1900, when significant hydrologic modification began, much of the mainstem Illinois River experienced a cyclical regime in which water levels gradually rose from the late fall through the spring and then fell to stable low levels in the summer (Sparks 1995). The construction of navigation dams and diversion of flows from Lake Michigan have generally increased the river water surface elevation and have altered the nature of the flooding regime along certain reaches of the river. Each dam keeps the water level in the upstream pool high enough to ensure a nine-foot navigation channel and as a result the floodplains immediately upstream of each dam are far more continuously inundated than they would be under undammed conditions (Sparks 1992). This eliminates the seasonal drying of the sediments that favored the establishment of vegetation in these areas (Sparks *et al.* 2000).

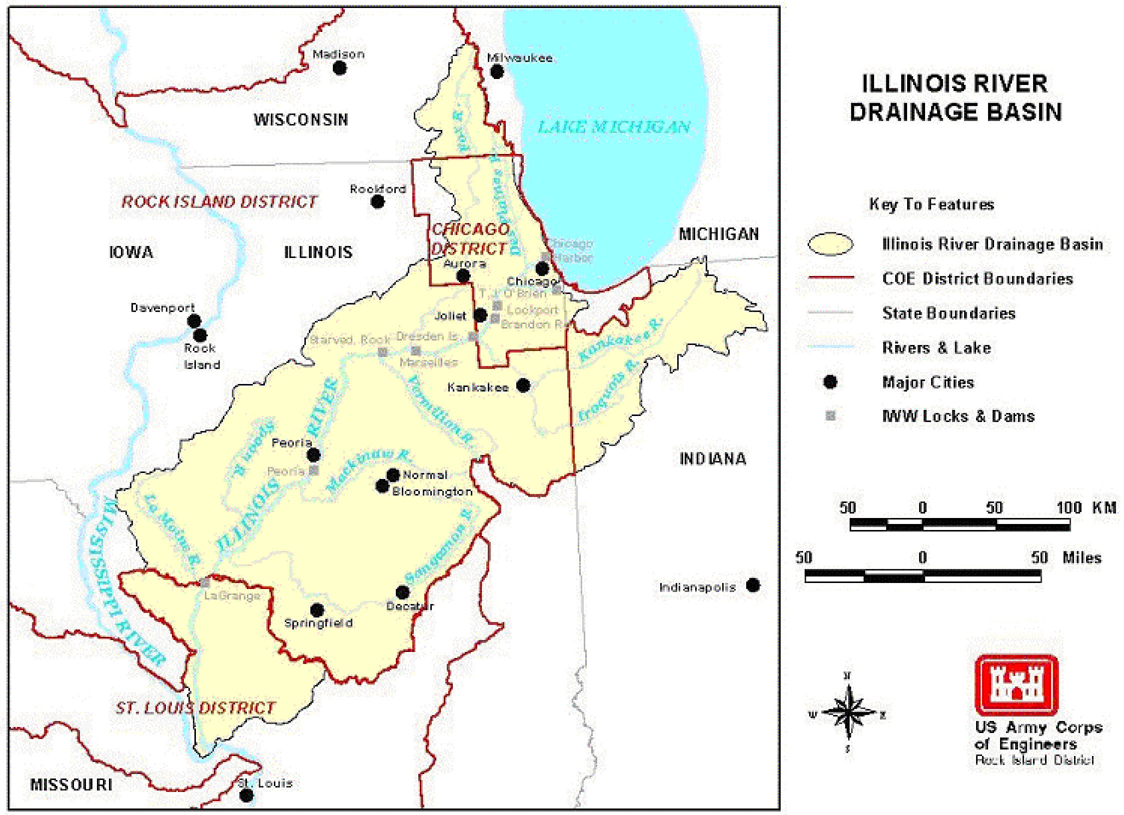

Figure 1. Illinois River Drainage Basin.

Dam Operations. Flows diverted from the Lake Michigan basin enter the Des Plaines River (which joins with the Kankakee River to become the Illinois River) at the Lockport Lock (Figure 1). The O'Brien Lock and Controlling Works, the Chicago River Lock and Controlling Works and the Lockport Powerhouse, Lock and Controlling Works together maintain water levels in the canal system upstream. Downstream of Lockport water levels are maintained by the Brandon Road Dam on the Des Plaines River, five dams on the Illinois River (Dresden Island, Marseilles, Starved Rock, Peoria and La Grange), and the Melvin Price Lock and Dam on the Mississippi River. The maintenance of water levels in the canal system upstream of Lockport Lock and Dam is generally achieved through operation of the Lockport Powerhouse, which is operated by the Metropolitan Water Reclamation District of Greater Chicago (MWRD).

Downstream from Lockport, all of the water-control structures are operated by U.S. Army Corps of Engineers personnel on a run-of-the-river basis with no provision for storage. The structures upstream of Peoria are permanent dams, but the two downstream can be raised or lowered depending on river conditions. The dams at Peoria and La Grange each consist of one 80-foot submersible tainter gate structure and a series of wicket gates that lay flat on the river bottom during high to moderate flows and are raised during low flows. The current operation of these dams generally involves raising either all or none of the wickets. The decision to lower the wicket dams occurs when the flow increases such that the tailwater of the dam approaches the level of the pool. As the river falls from a higher stage the lockmaster decides, based on experience and judgment regarding future river conditions, when to raise the wickets. Raising or lowering the wickets requires a steam-powered "maneuver" boat, a barge and a crew of five and takes several hours or more to accomplish. Wickets are raised, on average, 4.2 times per year at Peoria and 3.6 times per year at La Grange.

Effects of Fluctuations. Short-term water level fluctuations, that is, water levels that change on the order of 0.5 feet or more over the course of several hours to several days, have been implicated in degradation of Illinois River ecosystem function because of the stress that rapid changes in river conditions places on plants and animals. Increases in water level during the summer (especially June through September) can prevent the growth of aquatic plants in floodplain areas. Receding water levels are also a concern, as rapidly falling water levels in the summer (Koel and Sparks 2001), and any recessions during the winter (Raibley *et al.* 1997) have the potential to strand fish using the floodplain or other off-channel areas. The magnitude and frequency of water level fluctuations have notably increased in portions of the river since daily water level monitoring began in the 1880's and reducing the amount of water level fluctuation is likely to benefit native biological communities.

One source of fluctuation is the stormflows from the developed watersheds of tributary streams feeding the river. Current stormwater inflows generally have higher peak flows and lower baseflows than occurred under pre-development conditions; these result in rapidly rising and falling water levels and more uneven delivery of flows to the Illinois River. There is also evidence that changes in rainfall patterns and reduction of Lake Michigan diversion has led to a larger range of flows, and therefore water levels, throughout the year (Ramamurthy *et al.* 1989). Another potential cause of fluctuation is dam operations. Since the navigation system on the Illinois Waterway is operated to maintain water levels at the dam sites, the pools are not drawn down at any time but instead retain nearly constant water levels (with the exception of the Peoria and La Grange Pools during high-flow periods). Water level fluctuations are generally most evident in the upper regions of the pool including the tailwater of the upstream dam. These fluctuations are attributed to changing release flows from hydropower plants or from gate adjustments (Pegg 2001, Koel and Sparks 2001); maintenance activity has occasionally contributed to these fluctuations (*e.g.* Sparks *et al.* 2000). Additionally, water levels in the upstream portions of the river basin fluctuate in response to flood control operations in the Chicago Metropolitan area.

Historic Fluctuations

The water level fluctuations in the Illinois River system were evaluated at 20 sites (immediately above and below the dams from Lockport to La Grange, three gages in the LaGrange Pool and one gage each within the Starved Rock, Peoria and Alton Pools) using available water level records. Complete sets of bihourly water level records were available for water years 1989-2000, and daily water level records for water years 1979-2000 were also analyzed. Historical (pre-1900) records of daily water levels were analyzed at Henry, Copperas Creek, Havana, Beardstown and Meredosia.

A FORTRAN program was developed to count the number of fluctuations occurring over time windows of 6 hours, 24 hours and 120 hours (5 days). Each fluctuation was categorized by magnitude of water level change: 0.5 to 1.0 feet, 1.0 to 2.0 feet and greater than 2.0 feet. The fluctuation regime at each gage was therefore defined by the incidence of nine different types of fluctuation (six types for the daily records). Fluctuation regimes were analyzed over several time periods to evaluate effects of season, flow conditions and change over time. Based on the results of the fluctuation analyses it was possible to differentiate the behavior of the gages at the Starved Rock Lock and Dam and upstream (Upper River) from those downstream (Lower River).

Upper River. Throughout the year the fluctuation regime at each Upper River gage is largely controlled by a combination of the operations of the dams at both ends of its particular pool. Under normal operating conditions there are few fluctuations immediately upstream of the dam and any fluctuations are generally small in magnitude. Water levels immediately downstream of the dam may fluctuate due to changes in the flows required to maintain the constant water level upstream or due to changing downstream flow conditions; because of the controlled nature of the river these water level changes may be relatively abrupt. Stormwater from developed areas in the Upper River basin can lead to relatively rapid increases in river flows, and because there is little storage available in the pools the gates at the dams must be opened to pass the higher flows. Since flow response to gate operation is instantaneous the water levels downstream of the dams can change quickly and the stormwater effects move downstream.

The tailwater gages in the Upper River display more large fluctuations (greater than 2.0 feet) during high-flow years than average years. These are largely due to increased occurrence of large fluctuations during the high-flow seasons of those years (1990, 1991 and 1993). Examination of U.S. Geological Survey flow records indicates that flows in the river generally experience a number of fairly sharp peaks in the spring and that these peaks were both higher and more numerous during the high-flow years studied. Because of the small volumes impounded by the navigation dams, the large fluctuations during high-flow years can be tied to the more variable flows from the basin during those times.

Lower River. Unlike the Upper River where the dams are fixed structures and the controls imposed by the dams are fundamentally continuous throughout the year, the function of the dams on the lower river changes through the year and subsequently so does their effects on water level stability. During high flow periods the two Lower River dams, Peoria and La Grange, are kept lowered to the river bottom so that river flows and barge traffic pass unaffected over the top of the structures; this is referred to as “open river” conditions and occurred an average of 38 percent of the year at Peoria and 42 percent of the year at La Grange during the years 1939-1998. During these times the water level regimes are smoothed by flow attenuation from channel and floodplain storage within the unregulated pools. At locations downstream of the Peoria and La Grange Dams the smoother hydrographs result in a lower frequency of fluctuations and a lengthening of the time windows over which fluctuations occur relative to regulated conditions. However, the lack of dam control allows larger fluctuations in the pools during high-flow periods than occur during more regulated conditions. Essentially, during high flows the fluctuation regime in the Lower River is driven by the basin hydrologic regime and is unaffected by operations at the dam sites.

As river flow drops the wicket gates at Peoria and La Grange are raised to maintain adequate water levels for navigation. At this point the dams come into operation and the water level control becomes comparable to that observed in the Upper Pool: pools are held steady by adjusting the tainter gates at each dam to pass inflows to the downstream reach. While the dams are in operation fluctuations in the pools are small and infrequent but fluctuations downstream are larger and more frequent than those observed during open river conditions. Midpool reaches often display some combination of these phenomena based on the flow in the river and the distance from the downstream dam.

Historical Patterns. The comparison of the 1989-2000 fluctuation regime with that obtained from the 1979-1988 data indicate that the current regime has fewer fluctuations at most of the gage locations than it did in the recent past. Fluctuations decreased upstream of the Peoria Lock and Dam and at Beardstown and the La Grange Pool. At these locations there are currently fewer small (0.5 to 1.0 foot) and to a lesser extent moderate (1.0 to 2.0 feet) fluctuations; there was no change in large fluctuations at these locations. The improvement in small fluctuations indicates that there was probably an improvement in stormwater management, dam operations and/or coordination with hydropower facilities. The reduced pool fluctuations indicate that the dam operators are better able to maintain stable pool levels. Large

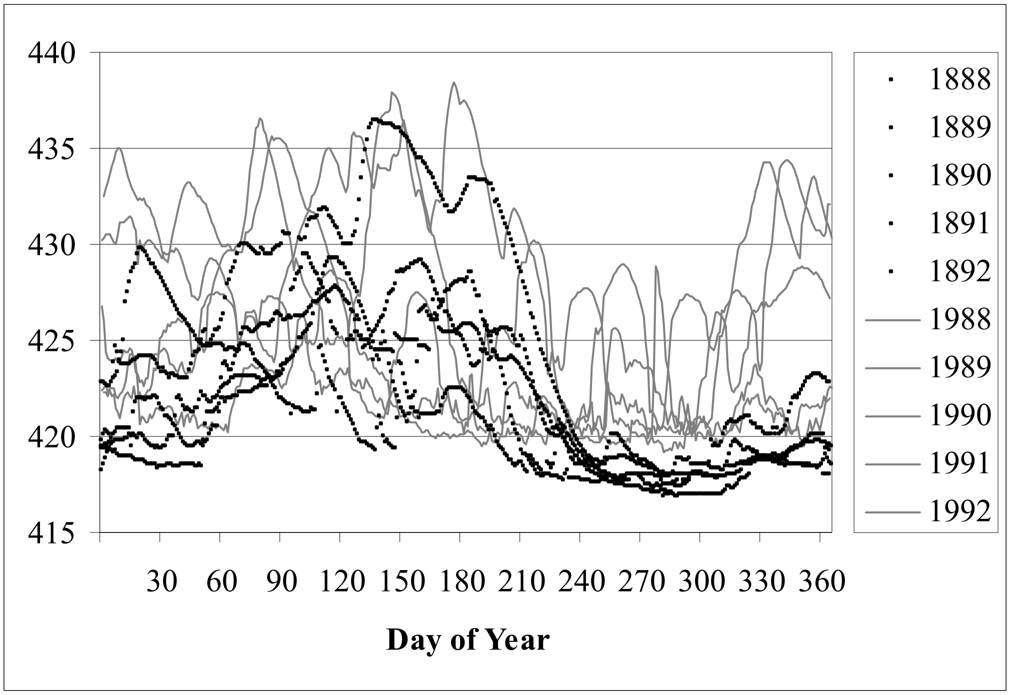

Figure 2. Comparison of Historical Daily Water Level Records at Meredosia.

fluctuations are primarily driven by large storm events so a lack of change in large fluctuations indicates that hydrologic responses to large storms have not greatly changed between these periods.

All of the historic gages available are located in the Lower River, and they show that changes in hydrology, river hydraulics and dam regulation have led to a regime that currently experiences more fluctuation than it did before 1900 (*e.g*. Figure 2). Except for the Henry site, which is relatively closer to historic values, the current fluctuation regimes have approximately three times as many 24-hour fluctuations and two times as many 5-day fluctuations; the fluctuation increases are not seasonal but occur throughout the year.

Upper Illinois Waterway Management

The operation of the canals in metropolitan Chicago and diversion from Lake Michigan play a significant role in the hydrologic regime of the upper reaches of the Illinois River. To maximize the flood control potential of the system, water is released from the Lockport Pool when a potential for significant rain is forecast for the Chicago area, resulting in pulses of water downstream with or without additional stormflows. Also, water from Lake Michigan, the Chicago River and the Calumet River are diverted to the Illinois River to maintain adequate water quality in the lake and downstream portions of the waterway and maintain navigation. However, the effects of these activities on downstream water levels, specifically in regard to water level fluctuations, have been a matter of much discussion.

Of the management issues in the canal portion of the Illinois Waterway, only the stormwater from the diverted rivers and canal storm operations are likely to contribute to water level fluctuations in the areas downstream of Lockport. Water supply pumpage, leakage and discretionary diversions for water quality tend to result in relatively constant flows that do not generate the pulses of water that lead to downstream fluctuations. Lockages do create hydraulic disturbances, but these are local events that do not have apparent significant effects beyond the immediate vicinity of the lock.

In response to forecasted storms the water level in the Lockport Pool is drawn down to improve drainage conditions upstream; drawdowns of 3.5 feet or greater were observed 152 times between January 1985 and December 2000. Even without the contribution from stormflows these drawdowns send pulses of water downstream and the ensuing rapid changes in dam gate settings cause water level fluctuations of 1 to 2 feet in the tailwaters of the dams as far downstream as Starved Rock. However, when the forecasted storms actually materialize the effects of the stormflows from various parts of the basin tend to mask and smooth the operation-induced fluctuations as the pulses of water pass downstream. These stormflows cause water level rises that, though not as abrupt, tend to be considerably greater in magnitude than the changes due to the gate changes, except in the uppermost pools.

Potential fluctuations due to stormwater operations in the Upper Illinois Waterway have been mitigated to some degree since 1989 by implementation of portions of the Tunnel and Reservoir Project (TARP), which is designed to capture combined sewer overflows, and improvements to the MWRD storm response system. These have allowed operators to shave some storm peaks and reduce the incidence of canal drawdown. However, the benefits of these improvements are limited because flows that are not the result of overflow from combined sewers are not controllable by the TARP and high peak flows, especially from the Des Plaines, DuPage and Fox Rivers, still have the potential to cause large water level fluctuations in the Illinois River.

Water Level Management, Modeling and Analysis

Analyses of water level records and UNET hydraulic modeling were used to evaluate the effects of water level management activities on the fluctuation regimes within the Illinois River system. Operation of the run-of-river dams was found to contribute to water level fluctuations in the system, mainly during low water conditions and in response to large stormwater pulses. In general, water level management tends to increase the rate of water level change in certain areas, specifically immediately downstream of dams, brought on by changing flows from the basin. Wicket dam operation was also found to cause water level fluctuations, but these were due to the hydraulic nature of changing between impounded and unimpounded conditions and so are not controllable by changes in operations.

Hydraulic modeling suggests that a number of management changes could reduce the fluctuations within the Illinois River system. A management scenario simulating smaller but more frequent gate changes at the dams in response to a more complete knowledge of inflows indicated that the total number of fluctuations observed along the river would significantly decrease; however, the reduced fluctuations would be observed during times of low water and so may or may not be as damaging as larger, out-of-banks events. Stormwater detention has the potential to reduce the larger fluctuations associated with storm events in the reaches immediately downstream of the detention facilities. In order to be fully successful, detention would have to be implemented throughout the basin, as rapidly fluctuating downstream inflows can mask upstream improvements. Improved coordination in anticipation of storm operations may reduce water level fluctuations associated with release of flows from Lockport. Finally, use of the limited storage in the system to reduce fluctuations by centralizing control and optimizing management may also provide benefits, but at this time the software routines required for system optimization have not yet been developed.

Water Level Modeling – Drawdown

The concept of occasionally lowering water levels in the Illinois River navigation pools aims to provide ecological benefits to areas of the pools that are continually inundated under current conditions. Outside of the navigation channel, much of the pool area immediately upstream of the dams once consisted of seasonally inundated mudflats (Sparks 1995). The seasonal exposure that the mudflats experienced prior to dam construction allowed their sediments to consolidate, allowing vegetation to establish. Under the current conditions flocculent silt and clay sediment that may accumulate in side channels and backwater areas does not become consolidated, remaining available for resuspension and unsuitable for support of most plant growth. Significant consolidation and benefits to plant growth have been observed in drawdowns in Illinois River and Mississippi River backwaters.

Several factors combine to determine the effects of a drawdown event, including:

- The duration of the event,
- The depth to which the water level is drawn down,
- The area of sediment exposed, and
- The month or season of drawdown.

Increased drawdown depth and implementation of added dewatering measures can increase sediment consolidation. It has been noted that 70 consecutive days without inundation between July 10 and October 1 are required for optimal growth and establishment of mudflat plants (Bellrose *et al.* 1983), but benefits have been observed with drawdowns of lesser duration (Atwood *et al.* 1996). Drawdown during the winter may provide the benefit of sediment compaction, although it would not permit vegetation to establish.

Hydraulic modeling was used to evaluate the potential to draw down the Peoria Pool, which was determined to have a higher potential to maintain a drawdown than the La Grange Pool downstream. Drawing Peoria Pool water levels down would have significant effects on navigation, recreation and infrastructure, the extent of which and mitigation costs would be expected to increase with drawdown depth. An existing UNET model of the Peoria Pool was used to simulate drawdown conditions using 58 years of recorded flow (1940-1997). Statistical analyses of the modeled water levels were used to determine the elevations for which continuous dewatering would be sustained for different recurrence intervals under the various drawdown scenarios. These elevations were used to determine the corresponding exposed area.

Although the greatest biological benefits might arise due to early season (June or July) drawdowns, flow conditions during those months make sustained exposure of the bottom unlikely; thunderstorms strong enough to cause the pool to rise are common enough that 30-day periods of continuous low flows rarely occur during these months. Drawdowns are most likely to be successful in the months of September or October, or if attempted over an extended period of time in the late summer, but navigational and recreational users would be greatly affected during those times. Drawdowns in December are less likely to succeed but may be desirable due to the lessened impacts during that month. Successful drawdowns to 0.5 feet below level pool would generally expose less than 1,000 acres of bottom area. The area exposed by a successful 1.5 foot drawdown (4,000-7000 acres) would be roughly twice the area exposed by a 1.0 foot drawdown (2,000-4,000 acres). A 2.0 foot drawdown would expose 7,000 to 10,000 acres. Successful uncontrolled drawdowns would expose considerably more area than the other drawdown scenarios, with 2 to 4 times as much area exposed as would occur with a 2.0 foot drawdown, or 22,000-25,000 acres.

Summary

The Water Level Management Analysis for the Illinois River Ecosystem Restoration Project was able to identify many sources of water level instability in the Illinois River system and determine the potential to reduce unnatural fluctuations. Changes to basin conditions have caused some of the instability, but a significant amount of the instability arises from water level management activities. Increased management of water level conditions has the potential to reduce fluctuations during low water conditions, although high water conditions are generally unaffected by river management activities. Also, the basin hydrologic regime limits the ability to sustain low water levels for extended periods of time, especially during the ecologically desirable period of June and July.

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